

BULLARD

**Design of an Artificial Lake
for Central Illinois Chautauqua**

Civil Engineering

B. S.

1913

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DESIGN OF AN
ARTIFICIAL LAKE FOR
CENTRAL ILLINOIS CHAUTAUQUA

BY

EDWARD WESLEY BULLARD

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1913

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UNIVERSITY OF ILLINOIS
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I recommend that the thesis prepared under my supervision by EDWARD WESLEY BULLARD entitled Design of an Artificial Lake for Central Illinois Chautauqua be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Instructor in Civil Engineering.

Recommendation approved

Ira O. Baker.
Head of Department of Civil Eng'g.



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DESIGN OF AN ARTIFICIAL LAKE FOR THE CENTRAL ILLINOIS CHAUTAUQUA.

INTRODUCTION.

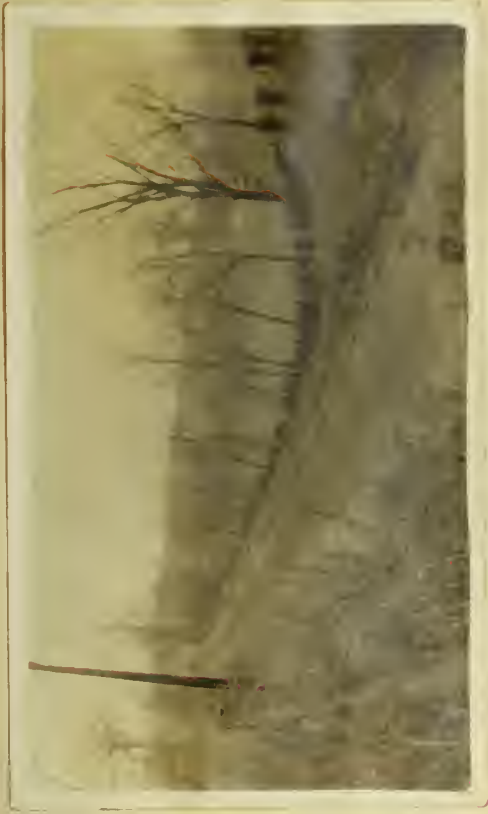
The Central Illinois Chautauqua is located in the central part of Sangamon County, Illinois, fifteen miles east of Springfield. The entire area of the grounds, about forty acres, is wooded land. The main part, about thirty acres, is situated on a level piece of ground 25 feet above the low lands which comprise the remaining ten acres. The low lands lie in a narrow valley drained by Clear Creek which runs diagonally across the northwest corner of the Chautauqua grounds and is crossed at the lower fence line by a branch of the Illinois Traction System. The track crosses the valley on an earth fill and the creek on a 75 foot trestle.

The Chautauqua Association has for some years contemplated constructing an artificial lake on the low lands for boating and bathing purposes. It has been proposed to connect the two ends of the earth fill by a dam just above the trestle, flooding the low lands of the Chautauqua and forming a broad channel for a considerable distance up the creek. Pictures of the creek bed, bottom land, and trestle are shown on Pages 2 and 3.

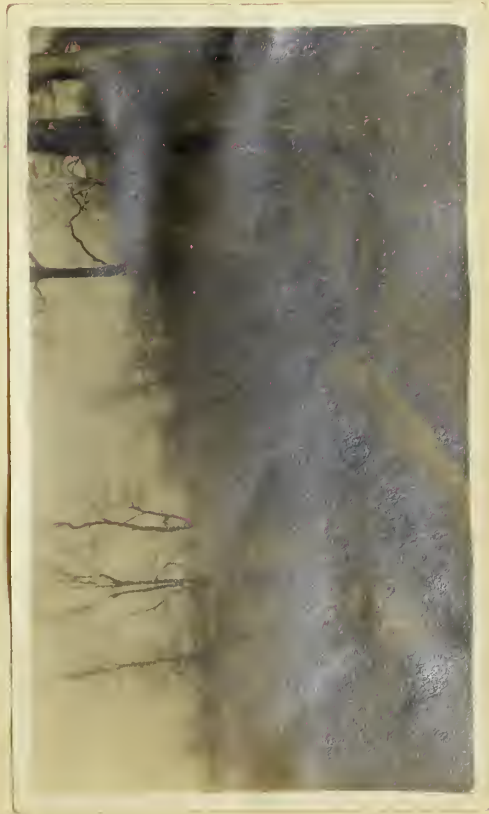
The purpose of this thesis is the design of this artificial lake. It was therefore necessary to make a topographical map of the proposed locality of the lake so as to determine the height to which the water should be raised, the amount of excavation necessary to get sufficient depth, and the area of the



Creek Bed 300 ft. above trestle.



Highway crossing valley above lake east of north.



Creek bed and lowland from trestle.



I. T. S. pile trestle.



Bottom land.

Looking northeast from a point on I. T. S. grade at 50 feet north of trestle.



Bottom land.

Looking southeast from a point on I. T. S. grade, 500 feet north and east of trestle.

land to be covered by water. It was then necessary to design a dam to close the opening in the earth fill and make an estimate of the total cost of constructing the lake.

The design is taken up under the headings: I, Field-Work; II, Office Work; and III, Specifications and Estimate of Cost. Under each, the methods used in the successive steps are given in detail.

FIELD WORK.

The first step necessary in the design was to take topographical field notes for plotting the map. To furnish horizontal control, a closed traverse was run by deflection angles around that part of the low lands likely to be flooded by the proposed lake. The magnetic bearing of the first line 0-1 was ascertained by several careful readings of the magnetic needle to be N $46^{\circ} 30'$ E. Transit stations were located at distances between 200 and 300 feet around the traverse. Notes for the traverse are shown on page 7. Distances were determined by chaining.

Vertical control for the survey was furnished by a line of spirit levels taken with the transit, starting from a bench mark on the root of an oak tree, with an assumed elevation of 100 feet. The elevations of several transit stations were determined from the same set-up of the transit. Care was exercised to obtain equal backsights and foresights for all turning points.

It was found necessary to extend a traverse line from station four, a distance of 1700 feet up the creek, so as to get all the required data for plotting. The notes for deflection angles, distances, levels, and topography were carried along at the same time. The distances between stations were taken with the stadia because great accuracy was not required. This method was found to be much faster than that used on the closed traverse. These data are given on pages 17 to 20.

The topography about each station was taken by the transit and stadia method, the points being located by azimuth from the traverse line, the vertical angle, and stadia distance. The sights were seldom over 300 feet in length. Readings were taken at all governing points for plotting the topography with a contour interval of one foot. The earth fill was located by taking points along the center and toe; the creek bed, by points along the bank.

A cross-section (page 16) of the creek near the proposed location of the dam was obtained by taking the elevation of points every $7\frac{1}{2}$ feet across the creek. The points were located with reference to the piles of the trestle. Borings for clay were made at several points on the cross-section (notes).

TRAVERSE AT LOW LANDS OF CHAUTAUQUA GROUNDS, MECHANICSBURG.

Station.	Dist. ft.	Deflect.	Mag. Bear.
Inst. Obj.	Chained.	Angle.	
0 - 1	223.4	0° 00'	N 46° 30' E
1 - 0		0° 00'	N 46° 30' E
1 - 2	310.5	R 15° 00'	N 61° 30' E
2 - 3	173.5	L 66° 00'	N 4° 45' W
3 - 4	269.35	R 89° 00'	N 84° 00' E
4 - 5	186.3	R 21° 00'	S 74° 30' E
4 - 6	253.0	R 60° 00'	S 35° 45' E
6 - 5	165.7	L 131° 08'	N 13° 00' E
6 - 7	246.7	R 108° 00'	N 72° 15' E
7 - 8	269.4	L 38° 00'	N 39° 00' E
7 - 2	175.2	R 44° 01"	S 63° 45' E
8 - 9	303.4	L 21° 30'	
9 - 10	290.3	R 22° 00'	
10 - 0	248.2	R 124° 51'	
0 - 1		R 23° 40'	
3 - 4		0° 0'	
4 - A	435	L 38 19	
A - B	740	L 12° 30'	
B - C	528	R 31° 30'	

LEVEL NOTES OVER TRAVERSE AT CHAUTAUQUA GROUNDS, MECHANICSBURG.

Station.	Back sight. +	H.I.	Fore sight. -	Elev.	
B.M.1	11.59	111.59		100.00	Root of oak tree.
0			12.55	99.1	
1			10.60	101.0	
2			11.3	100.3	
3			8.3	103.3	
TP	5.06	109.20	7.45	104.14	
4			8.7	100.5	
5			9.45	99.8	
6			5.2	104.0	
7			9.6	99.6	
TP	12.18	111.99	9.44	99.71	
8			10.8	101.1	
9			8.9	103.0	
B.M.2	1.35	104.91	8.33	103.56	Root of oak tree.
10			5.9	99.0	
0			5.9	98.0	
B.M.1			4.88	100.03	1st B.M.
TP.	0.95	101.31	4.55	100.36	
			10.1	91.2	Flow line of creek under bridge.
B.M.3				104.14	Inst. at Sta.A.
A	1.53	105.69	2.24	103.45	
B.M.4	8.33	108.38		100.5	Inst. at Sta.A.
B			6.38	102.0	
B.M.5	33.2	106.67		103.45	Inst. at Sta.B.
C			3.75	102.92	

TOPOGRAPHY AT CHATAUQUA GROUNDS, MECHANICSBURG, ILLINOIS.

Instrument at Sta. 10. Elev. 99.0

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.
		o "	o "	

9

0 00

H.I. 5.1'

242

0 00

+ 0 30

100.1

81

0 00

+ 0 05

99.1

71

30 00

+ 1 15

100.5

160

30 00

+ 5 30

113.6

HI 4.75'

270

5 00

+ 0 40

102.1

270

11 08

+ 1 57

104.9

112

11 23

+ 1 35

101.8

260

359 30

+ 0 40

102.0

B.C.

170

350 15

+ 6 08

94.4

B.C.

130

330 50

+ 0 06

99.2

B.C.

115

316 32

- 1 23

96.6

B.C.

98

316 32

- 0 20

98.5

10' from B.C.

109

215 07

+ 4 37

107.1

Center track.

117

238 50

+ 4 20

107.8

" " center of creek.

137

254 57

+ 1 20

102.2

Center of track.

182

272 40

+ 1 35

104.0

" "

147

272 40

- 0 11

98.5

F.L. and Toe S.

105

255 47

+ 1 35

102.9

Toe of slope and bank of creek.

133

178 49

+ 1 25

103.3

Center track.

100

178 49

+ 0 06

98.8

Toe bank.

137

154 55

- 0 11

98.6

" "

184

154 55

+ 2 26

106.1

" "

214

142 53

+ 2 03

106.6

211

142 53

+ 0 34

101.1

I.T.S.F. and Toe slope.

310

137 39

+ 1 51

108.0

TOPOGRAPHY AT CHATAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.	
		o "	o "		
320	132 26	+ 1 45	108.7	I.T.S. F. and T.S.	
312	134 05	+ 0 41	102.7		
225	123 53	+ 1 05	103.3		
125	123 53	+ 1 36	102.5		
68	225 55	+ 0 16	99.3		
99	238 20	- 1 30	96.4		
Instrument at O. Elev. 99.0 H.I. 4.93					
1		0 00			
19	250 40	- 10 06	97.8		
53	250 40	+ 0 43	99.6		
58	196 57	- 3 40	98.6		
122	185 03	- 1 40	98.6		
180	181 50	- 0 39	97.0		
127	169 57	+ 0 02	99.0		
108	159 25	0 00	99.0		
107	140 47	- 1 30	96.2		
89	140 47	+ 0 19	98.5		
128	118 12	- 1 20	96.1		
119	72 08	+ 0 10	98.6		
132	56 22	+ 0 08	98.7		
97	48 21	0 00	99.0		
155	38 25	+ 0 17	98.2		
168	22 25	0 08	98.6		
235	12 20	- 0 16	97.9		
195	0 00	- 0 30	97.3		

TOPOGRAPHY AT CHAUTAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.
		° "	° "	
1		0 00		
	139	0 00	- 0 45	97.2
	63	0 00	- 1 45	97.1
	51	0 00	- 1 43	100.5
	112	340 53	- 0 40	97.7
	70	338 40	- 2 25	96.2
	41	338 40	+ 0 30	99.5
	29	306 20	+ 5 00	101.5
	78	260 07	+ 5 51	106 9
	106	310 26	+ 4 08	106.6
	70	310 26	+ 0 45	99.9
	230	336 05	+ 2 08	107.6
	170	336 05	+ 1 02	101.9
	314	340 45	+ 0 50	104.2
	308	343 45	+ 0 36	102.1
	303	344 45	+ 1 00	104.1
	266	345 26	+ 0 23	100.8
	244	352 00	+ 0 14	100.0
	227	0 35	+ 0 30	101.0
	45	45 30	- 1 50	97.6
	39	123 20	- 1 25	98.1
	57	147 20	+ 0 09	98.9
-1	54	156 11	+ 0 00	100.3
Instrument at 2.		Elev. 100.3	H.I. 5.13	
	124	42 55	+ 18	100.9

TOPOGRAPHY AT CHAUTAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.	
		° "	° "		
174		36 45	+ 0 30	101.8	
211		36 45	+ 2 08	108.2	
125		19 52	- 0 47	98.6	
178		359 20	- 0 41	98.2	
257		358 40	- 0 00	100.3	Edge of bank
250		8 20	- 0 15	99.2	
200		6 50	+ 0 35	98.6	
147		356 55	- 0 40	98.6	
166		343 30	- 0 10	99.8	
65		357 15	- 0 15	180.0	
-3 Instrument at 4.		0 00	Elev. 100.5	H.I. 5.1	
180		123 45	+ 1 40	105.7	Center track
153		124 15	+ 1 30	104.5	Center ditch
226		66 15	+ 1 36	106.6	
92		64 15	- 0 05	100.4	
109		37 40	- 1 36	97.5	B.C.
342		22 00	+ 0 04	100.9	Center highway.
200		22 00	+ 0 04	100.7	
36		358 15	- 3 14	98.5	B.C.
28		358 00	- 8 35	96.4	Top water
116		356 45	- 0 15	100.0	Corn field
141		234 55	- 1 15	97.5	B C
276		208 21	0 00	100.5	
66		239 40	- 0 54	99.5	

TOPOGRAPHY AT CHAUTAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.	
Instrument at 6.		Elev. 100.4	H.I. 4.94.		
	0	"	0	"	
-4		0 00			
	89	64 85	- 1 45	101.3	Fence line.
	87	357 00	- 2 30	100.2	"
	172	330 15	- 1 38	99.1	"
	195	321 15	- 1 52	98.7	B C
	172	316 40	- 1 21	100.0	
	186	291 25	- 1 20	99.7	
	135	281 40	- 1 28	100.6	
	108	262 50	+ 0 49	105.5	
	234	286 45	- 1 06	99.5	
	305	297 35	- 0 43	100.2	B C
	48	126 25	+ 5 03	106.5	
	117	80 09	- 0 22	103.3	F L
	470	56 20	- 0 07	103.0	S.W.corner floor bridge
	440	69 50	- 0 21	101.3	C Highway
	175	120 20	+ 3 30	114.6	H F L
	190	143 20	+ 4 50	120.0	H F L
Instrument at 7.		Elev. 99.6	H.I. 5.08		
	0	00			
6					
	60	261 30	+ 1 05	100.7	Edge B.C. 11.6
	66			93.1	Rod reading Top of water
	143	195 30	- 1 00	97.1	B.C.
	123	195 15	+ 0 10	100.0	Near C.
	171	198 25	+ 0 20	100.6	6' from B.C.
	210	180 40	0 00	99.6	B.C.

TOPOGRAPHY AT CHAUTAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.	
		o "	o "		
212		142 00	+ 0 15	100.5	
194		133 40		97.3	Rod reading 7.42 30 ft. from B.O.
203		109 25	+ 1 25	104.6	
51		120 00	+ 1 55	101.3	
89		64 10	+ 1 00	101.1	
87		9 10	+ 0 20	100.1	
91		274 35	- 1 25	97.5	
96		230 00	- 1 15	97.5	
142		113 20	- 1 10	96.8	
Instrument at 8.		Elev. 101.1		H.I. 5.08	
7		0 00			
156		145 50	+ 1 20	103.2	
160		223 55	+ 0 35	101.2	B.C.
107		242 55	- 1 10	97.4	"
82		277 35	- 0 50	98.4	"
128		315 20	- 1 45	95.7	
195		321 10	- 1 15	95.4	
182		300 05	- 0 10	99.0	
129		300 45	- 1 35	96.1	B.C.
160		280 00	- 0 22	98.6	
105		280 20	- 2 05	96.0	
102		281 00	- 9 25	91.8	
117		206 40	- 2 05	95.4	
136		256 40	- 0 40	98.0	
186		256 40	- 0 10	99.1	

TOPOGRAPHY AT CHAUTAUQUA GROUNDS, MECHANICSBURG. (Continued).

Station.	Ob.dist.	Azimuth.	Vertical angle.	Elev.	
		o "	o "		
165	237 30	- 1 20	95.8	B.C.	
209	237 30	- 0 20	98.4		
Instrument at 9.	Elev. 103.0		H.I. 5.03		
	0 00				
155	80 25	+ 10 05	129.8		
188	143 33	+ 8 00	128.8		
51	143 33	+ 5 00	107.4		
50	212 55	- 2 00	101.3	B.C.	
178	221 55	- 1 15	99.2		
131	179 25	- 1 20	99.0		
51	335 20	- 2 55	100.4		
61	310 10	- 10 05	92.5	Creek top water.	
87	310 10	- 8 00	90.0		
54	267 20	- 1 20	101.7		
110	270 00	- 1 55	99.4		
198	209 30	- 1 10	99.0		
242	227 40	- 2 35	92.5		
216	225 35	- 1 00	99.3		
140	235 35	- 2 55	95.9		
111	235 35	- 3 00	97.2		
73	235 35	- 8 30	92.4		

Locating Railroad Trestle.

station.	Distance.	Azimuth.
----------	-----------	----------

Instrument at Sta. 10.

o "

0 00

111	R 48 05	North end of trestle.
-----	---------	-----------------------

13	R 25 00	South end of trestle.
----	---------	-----------------------

Cross-section of Creek at Trestle.

Station.	Back sight. +	H.I.	Fore sight. -	Elev.
----------	---------------------	------	---------------------	-------

B.M.	4.19	104.5		100.36	
1			5.2	99.3	South end of trestle.
2			5.6	98.9	15' from south end of T.
3			8.5	96.2	22' " "
4			10.8	93.7	30' " "
5			12.6	91.9	37'6" " "
6			10.2	94.3	45' " "
7			8.0	96.5	60' " "
8			6.1	98.4	67'6" " "
9			1.6	102.9	North end of trestle.

TOPOGRAPHIC NOTES FOR TRAVERSE EXTENDED.

Station.	Back sight. +	H.I.	Fore sight -	Elev.	Dec.2,1913. Clear and Cold.
B.M. A	1.55	105.69	2.24	104.14 103.45	B.M. on stake.

Instrument at 4. Elev. 100.5 H.I. 5.09.

Distance.	Azimuth. o "	Vertical angle. o "	Elev.	
	0 00			
205	196 30	+ 2 45	110.3	Edge of track
176	231 10	+ 4 22	113.8	" "
205	258 20	+ 3 42	113.6	" "
248	292 10	+ 1 44	108.0	Corn field.
128	292 10	+ 0 30	101.5	" "
45	292 10	- 1 41	98.2	
174	236 00	+ 1 30	105.0	Under culvert.
120	180 00	+ 0 09	100.8	
152	325 50	- 1 20	97.0	

	Back sight. +	H.I.	Fore sight. -	
B.M. A	8.33	108.38	6.38	100.5 102.0

Distance.	Azimuth. o "	Vertical angle. o "	Elev.
-----------	-----------------	---------------------------	-------

Instrument at Sta.A. Elev. 103.45 H I 5.28

	0 00			
B	740	12 30	- 0 07	102.1
	30	152 20	- 0 45	103.
	73	140 25	- 0 20	102.9
	109	130 50	- 1 10	101.2
	242	131 10	+ 0 15	104.9
				Corner bridge. " "

TOPOGRAPHI NOTES FOR TRAVERSE EXTENDED (Continued).

Station.	Distance.	Azimuth.		Vertical angle.		Elev.	
		o	"	o	"		
415		111	50	+ 0	06	104.8	
316		80	40	- 0	06	102.9	
183		307	30	+ 2	20	110.8	
208		344	15	- 0	30	101.6	
480		344	15	0	00	103.4	
446		8	30	- 0	20	100.9	B.C.
530		14	30	- 0	14	101.3	B.C.
305		32	10	- 0	22	101.5	B.C.
316		30	40	- 0	50	98.8	
146		58	50	- 1	55	98.5	
71		62	15	- 4	30	97.9	
49		117.15		- 1	30	93.8	Top water.
140		163	46	- 4	06	93.6	" "
B.S.		H.I.		F.S.			
	3.32	106.67				103.45	
C				3.75		102.9	

Instrument at B. Elev. 102. HI 4.09
 Distance. Azimuth. Vertical angle.

		o	"	o	"		
A		0	00				
C	528	31	30	+ 0	08	103.0	
	126	160	15	- 2	45	95.9	Top water.
	145	123	30	- 0	55	97.2	B.C.
	265	110	50	- 0	40	99.0	B.C.

TOPOGRAPHY NOTES FOR TRAVERSE EXTENDED (Continued).

Station.	Distance.	Azimuth.	Vertical angle.	Elev.	
		o "	o "		
232		101 10	- 0 36	98.6	High point of neck
177		101 20	- 0 00	102.0	B.C.
127		99 20	- 1 20	99.1	B.O.
80		99 20	- 0 06	101.8	B.C.
254		359 20	+ 0 06	102.4	
385		320 50	+ 1 12	103.3	Corn field.
625		337 30	+ 1 43	120.5	Corn field
368		358 40	+ 0 06	102.6	B.C.
365		29 30	- 0 06	101.4	B.C.
607		68 20	+ 1 48	121.2	Fence line
380		68 20	+ 0 35	105.8	
140		68 20	+ 0 07	102.3	B.C.
Instrument at C. Elev. 103.0 HI 5.05					
B		0 00			
301		355 35	- 0 33	100.1	B.C.
444		340 00	- 0 16	101.0	B.C. and drain.
460		340 60		96.6	Rod reading 11.39 top water.
646		340 40	- 0 12	100.8	B.C.
952		314 40	+ 0 30	111.3	
626		314 15	0 00	103.0	Ravine.
340		314 15	+ 0 02	103.2	
208		314 15	+ 1 00	107.9	
35		114 30	- 13.25	96.0	Top water
29		49 00	- 5 40	100.2	B.C.

TOPOGRAPHY NOTES FOR TRAVERSE EXTENDED (Continued).

Station.	Distance.	Azimuth.	Vertical angle.	Elev.
		o "	c "	
	66	48 45	+ 0 45	103.2
	376	48 45	+ 3 00	113.0
	210	48 45	+ 0 45	105.7

Borings for clay at foundation. Depth 3' 20 feet upstream from pile trestle between pile 3 and 4 or point 5 on cross section. Depth 7' 20 feet upstream from pile 5 or point 7 on cross section. Beginning of clay; drill too short.

OFFICE WORK.

After the field work was finished, the notes were completed by calculating the elevations of the points with the stadia slide rule. The map was then plotted to a scale of 40 feet to 1 inch. The traverse was plotted by the tangent method and checked with a protractor. The points establishing the creek bed, railroad, fill, fence line, and contours were plotted with a protractor and scale. The contours were drawn in by interpolating between the points. The map was first drawn on paper to the large scale. It was then traced and reduced to conform to the size of the thesis. Map in back of thesis.

Referring to the map it is seen that the hundred foot contour is the height to which the water can be raised without overflowing a large area of valuable farm land not owned by the association. If the water level is made lower than this elevation, more excavation would have to be done in order to get the required depth of 3 feet. By raising the water to the 100 foot elevation with a dam across the stream bed, connecting the two ends of the earth fill, the low lands of the Chautauqua will be flooded to a depth of one-half to three feet and a broad channel will be formed up the stream bed. That part of the grounds shown on the map which is not covered to sufficient depth should be lowered by excavation. It is evident therefore, that the crest of the dam should be at elevation 100.

Several types of construction for the dam were considered. Because of the large amount of flood overflow, an earth

dam is economically impossible. A wooden dam would be impracticable because the lake would probably be drained during part of the year, a condition which would be unfavorable to this form of construction because of the tendency for wood to decay when covered with water only part of the time. Masonry seemed preferable, and as stone is difficult to get in the locality it was decided to construct the dam of concrete. The length of the dam crest, in order to discharge the overflow under the trestle was selected as 60 feet. After calculating the amount of flood overflow, it was decided to construct a gate-way 10 x 8 feet at one end, to help take care of the floods and to form a passage for draining the lake at times of ordinary flow.

A minimum depth of three feet being required for boating purposes, the bottom of the lake should be at an elevation of 97 feet or less. Where the earth is above this elevation it should be excavated. The area over which this excavation will extend and the volume to be taken out may be calculated from the topographical map.

The excavations for the dam should be carried down to solid clay, which was found to be at an elevation of 88 feet. Sufficient horizontal area will be required to give room for setting the forms and constructing the dam. The volume may be obtained by the use of the cross-section of the dam site and the horizontal area to be excavated.

The earth excavated may be used in the construction of the earth fill and to raise the land adjacent to the lake.

DESIGN OF THE DAM.

For the purpose of designing the dam to take care of the discharge, at time of maximum rainfall, the flood flow must be approximately ascertained. A topographical map has not been made of this district; it was necessary, therefore, to estimate the drainage area from a map (Plate II) taken from the county atlas. The ridge line was estimated as shown on the map. It is seen that the creek valley is approximately 6 miles long and 2 miles wide making a drainage area of about 12 square miles. The length of the main channel is about 8 miles with tributaries about 2 miles long. By observing this stream and knowing the velocity of flow in similar channels the time is estimated at three-quarter hours for the water to reach the tributaries from the most remote part of the area; 2 hours to flow 2 miles down to the main channel, and $5\frac{1}{2}$ hours to flow 8 miles down the main channel; making a total of 8 hours for the water to concentrate at the dam site.

The maximum rainfall for 8 hours taken from Toureaure's maximum rainfall curve for the central states is 5.5 inches. Estimating the runoff as 40 per cent for plowed ground and meadow land, the total discharge in cubic feet per second may be calculated.

If $5.5 \times 40 = 2.2 =$ discharge in 8 hours.

$$\frac{1}{\text{sq. mile in 8 hours}} = \frac{\frac{1}{12} \times 27,900,000}{8 \times 60 \times 60} = 80.7 \text{ cubic feet per sq. mile.}$$

$$80.7 \times 2.2 = 177.4 \text{ cu. ft. per sec. per sq. mile}$$

$$177 \times 12 = 2130 \text{ cu. ft. per sec. per sq. mile} = \text{total discharge.}$$

Using the empirical formula, $Q = \frac{200 M^{\frac{6}{5}}}{M}$, the total discharge is found to be smaller than by using the rational method above.

If Q = cu. ft. per sec. per sq. mile,

M = area in sq. miles,

$$\begin{aligned}\text{Then } Q &= \frac{200 \times 12^{\frac{6}{5}}}{12} \\ &= \frac{200 \times 7.932}{12}\end{aligned}$$

$$= 133 \text{ cu. ft. per sec. per sq. mile.}$$

$$12 \times 133 = 1590 \text{ cu. ft. per sec.} = \text{total discharge.}$$

Taking the discharge as 2100 cubic feet per sec. and the dam crest as 60 feet in length, the height of overflow may be calculated from Bazin's formula $h^{\frac{3}{2}} = \frac{Q}{cl}$

If Q = 2100 cu. ft. per sec. = total flow,

c = 4 - a constant varying with the shape of crest and height of overflow,

l = 60 feet - length of crest.

h = height of flow over crest in feet,

$$\text{Then } h^{\frac{3}{2}} = \frac{2100}{60 \times 4}$$

$$= 8.75$$

$$h = 4.48 \text{ ft.}$$

A gateway 10 feet long and 8 feet deep constructed in the dam will lower this depth of overflow. The amount discharged through a submerged gateway is estimated by Herschel's formula.

$$Q' = 3.33 l (nH)^{\frac{3}{2}}$$

If Q' = discharge in cu.ft. per sec.

l = 10. ft. length of gate.

H = 11 feet head on upstream side of dam

H' = 8 feet head on downstream of dam

n = .787 - a variable depending on the ratio $\frac{H'}{H}$

$$\begin{aligned} \text{Then } Q' &= 3.33 \times 10 \times (.787 \times 11)^{\frac{3}{2}} \\ &= 3.33 \times 10 \times 25.6 \\ &= 928 \text{ cu.ft. per sec.} \end{aligned}$$

and the height of overflow would be lowered to $h^{\frac{3}{2}} = \frac{2100 - 928}{50 \times 4}$

$$= 5.86$$

$$h = 3.25 \text{ feet.}$$

This head of overflow will cause the water to cover a considerable amount of low land in the valley. The greater part of this land is overflowed at the present time at maximum flow. It is mostly meadow land which would not be injured to any great extent during the short time this head would be maintained. The water at maximum flood will be raised to elevation 103.5 feet and will flood the ground enclosed by a contour at this elevation.

Taking the top of the dam at elevation 100 and the foundation on solid clay at elevation 88 the height will be 12 feet. The section is designed by Turneure's method.

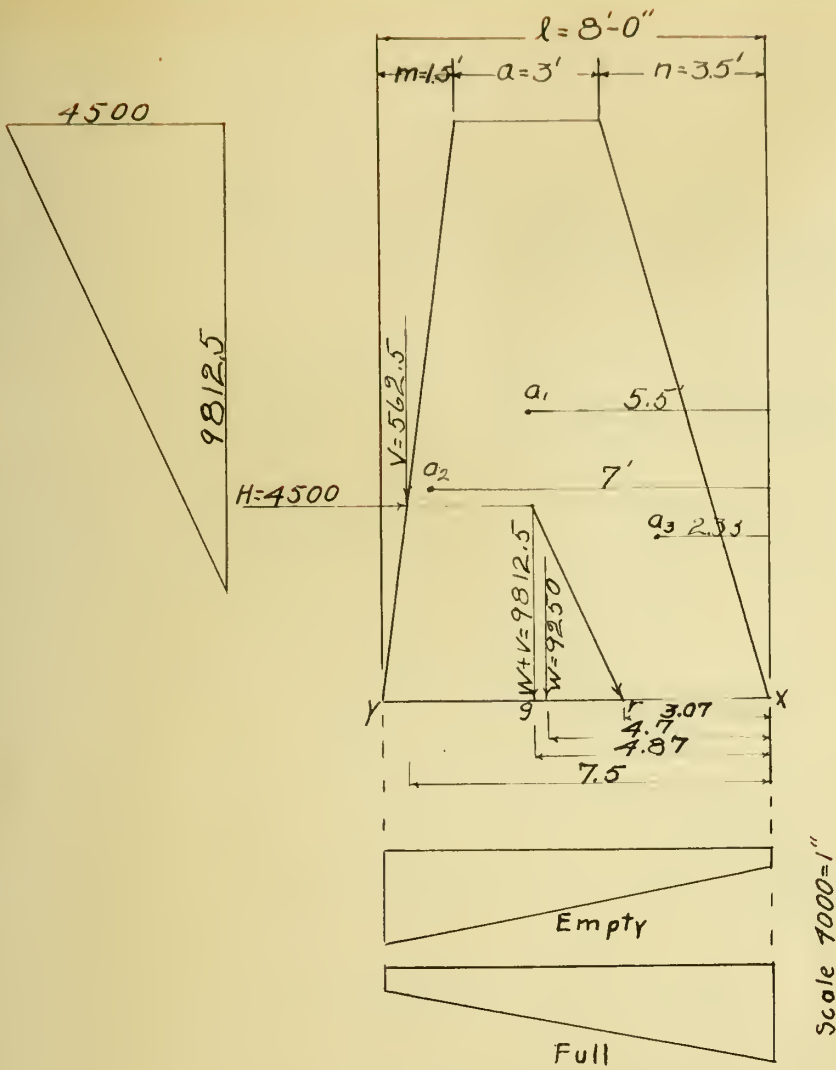


Figure I.

If $h = 12$ ft. height of dam

$m = 1.5$ ft. horizontal distance from heel of dam
to upstream edge of crest

$a = 4$ ft., width of crest

$n =$, horizontal distance from toe of dam to
downstream edge of crest

$w = 62.5$ lbs. = weight of 1 cu.ft. of water

$w' = 140$ lbs. = weight of 1 cu.ft. of concrete

$g = 2.25$, ratio of $\frac{w'}{w}$

$P_h = \frac{wh^2}{2}$ = horizontal pressure of water,

$P_v = \frac{wmh}{2}$ = vertical pressure of water

$A = \text{variable} = a^2 + 2am + \frac{h^2}{g} + \frac{m^2}{g}$

$B = \text{variable} = \frac{m}{g} - \frac{m}{2} + \frac{g}{2}$

$l = A + B^2 - B$, length of base of section.

$$\text{Then } P_h = \frac{62.5 \times 12^2}{2} = 4500$$

$$P_v = \frac{62.5 \times 1.5 \times 12}{2} = 562.5$$

$$A = 3^2 + 2 \times 3 + 1.5 + \frac{12^2}{2.24} + \frac{1.5^2}{2.24}$$

$$= 83.255$$

$$B = \frac{1.5}{2.24} - \frac{1.5}{2} + \frac{3}{2}$$

$$= 1.42$$

$$l = 83.225 + 1.42^2 - 1.42$$

$$= 7.82 \text{ ft. or say } 8 \text{ feet.}$$

$$\text{Then } n = 8 - 1.5 + 3 = 3.5 \text{ ft.}$$

The section was tested for stability by the graphical method as shown in Figure I.

All moments taken about (x) toe of dam.

Area of section = 66 sq. ft.

$$\text{Center of gravity} = \frac{36 \times 5.5 + 9 \times 7 + 21 \times 2.33}{66} = 4.7'$$

If $P_h = 4500$ applied at $\frac{1}{3}$ the height h

$P_v = 5625$ applied at $\frac{1}{3}$ the height h

$$W = 66 \times 1 \times 140 = 9250$$

$$n = \frac{562.5 \times 7.5 + 9250 \times 4.7}{9812.5} = 4.8.7 \text{ applications.}$$

$$\text{of } P_v + W = g$$

Distance from center of gravity (g) to application of resultant of $P_v + W$ and $P_h = 1.8$ ft., graphical solution = gr . Factor of safety against overturning = $\frac{g}{g} \frac{x}{r}$

$$\text{Then } \frac{g}{g} \frac{x}{r} = \frac{4.8.7}{1.8} = 2.71$$

Factor of safety against sliding on the clay foundation = $\frac{(P_v + W)C}{P_h}$, where C is coefficient of friction of clay = .50

$$\text{Then } \frac{(P_v + W)C}{P_h} = \frac{9812.5 \times 50}{4500} = 1.08 \text{ for dam alone.}$$

Weight of the apron is equal to $16.66 \times 140 = 2335$ lbs. per cu.ft.

$$\text{The factor of safety against sliding for the dam and apron} = \frac{(9812.5 + 2335) \times .50}{4500} = 1.35$$

Solving for the pressure at the heel and toe when the lake is full, the formula

$$P = \frac{W + Pv}{l} \pm \frac{6W}{l^2} \cdot v \text{ is used.}$$

W = weight of 1 linear foot of dam.

Pv = vertical pressure of water

l = length of base

Or = distance of application on point of $P = .9$

$$\text{Then } P = \frac{9812.5}{8} \pm \frac{6 \times 9250 \times .9}{8^2}$$

$$P = 445 \text{ at heel}$$

$$= 2007 \text{ at toe}$$

When the lake is empty the formula becomes

$$P = \frac{W}{l} \pm \frac{6WOr}{l^2}$$

$$\text{Then } P = \frac{9256}{8} \pm \frac{6 \times 9250 \times .9}{8^2}$$

$$P = 374 \text{ at toe}$$

$$= 1936 \text{ at heel}$$

The result of this design makes the dam 12 feet high with a crest of 60 feet in length and a cross-section, having a base 8 feet, crest length 3 feet and a batter of one-eighth on the upstream side and $\frac{3.5}{12.5}$ on the downstream side. Wing walls will have to be constructed at the ends of the dam to support the earth fill and an apron at the toe to protect the dam from undermining. A gateway 10 feet long and 8 feet deep is placed at the end of the dam to drain the lake. To increase the bearing pressure of the soil and guard against sliding, piles should be placed every 6 feet along the dam at the heel and toe. Plans

and specifications are given on pages

EARTH WORK.

The masonry dam must be connected with the earth fill of the railroad by an earth embankment. The top of this embankment should be $2\frac{1}{2}$ feet above maximum high water line at an elevation of 106. The embankment should be made impervious with side slopes of 3 to 1 on the upstream side and connecting with the earth fill on the downstream side.

The volume of earth to be used in the embankment is estimated as follows: Taking the cross-section at 90 sq. ft. and a length of 150 feet on each side of the dam the amount is $90 \times 300 = 27,000$ cu.ft. or 1000 cubic yards excavation.

In estimating the amounts of earth to be excavated, the topographical map was used. The area was divided into rectangles of 40 feet square and the depth of excavation at the corners taken from the contours. The volume was then calculated by the formula

$$V = \frac{A (h_1 + 2 h_2 + 3 h_3 + 4 h_4)}{4 \times 27}$$

Where V = volume of cubic yards

A = area of 1 rectangle in sq. ft.

h = summation of corner depth, the subscripts noting the number of times used.

Then A = $40 \times 40 = 160$ sq. ft.

($h_1 + 2 h_2 + 3 h_3 + 4 h_4$) = 481 Pages

$$V = \frac{160 \times 481}{4 \times 27}$$

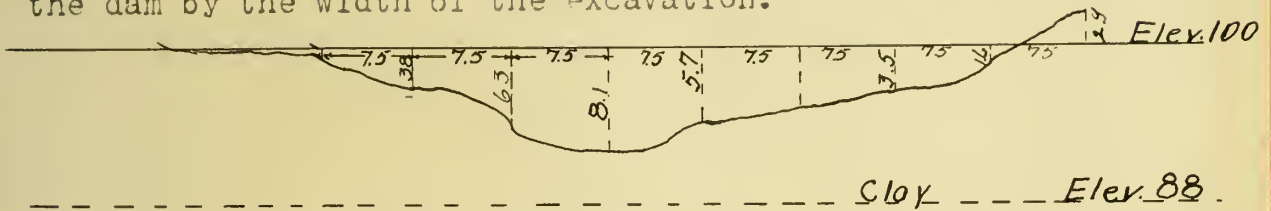
$$= 7925 \text{ cubic yards.}$$

No.	Elev.	X-subscript.	H.	H x
1	99	1	2	2
2	99	2	2	4
3	98.5	2	1.5	3
4	98	2	1	2
5	98.5	2	1.5	3
6	99	2	2	4
7	98	2	1	2
8	98	2	1	2
9	98	2	1	2
10	99	2	2	4
11	100	2	3	6
12	100	2	3	6
13	100	2	3	6
14	100	2	3	6
15	101	1	4	4
16	98	3	1	3
17	98	4	1	4
18	98.5	4	2.5	10
19	99.5	4	2.5	10
20	99	4	2	8
21	97	4	0	0
22	97	4	0	0
23	97	4	0	0
24	97	4	0	0
25	99	4	2	8
26	99	4	2	8
27	98	4	1	4
28	98	5	1	5
29	98	1	1	1
30	99	1	2	2
31	98.5	4	1.5	6
32	98	4	1	4
33	97	4	0	0
34	97	4	0	0
35	97	4	0	0
36	97.5	4	0.5	2
37	97.5	4	0.5	2
38	100	4	3	12
39	99.5	4	2.5	10
40	98.5	4	1.5	6
41	98	4	1	4
42	97.5	4	0.5	2
43	99	3	2	6
44	100	1	3	3
45	101	1	4	4
46	101	3	4	13
47	99	4	2	8
48	98	4	1	4
50	98.5	4	1.5	6
51	99	2	4	8
52	99	4	2	8
53	98	4	1	4
54	98	4	1	4
55	98	4	1	4

No.	Elev.	x subscript.	H.	H x	.	32.
56	98	3	1	3		
57	99	2	2	4		
58	99	3	2	6		
59	98	3	1	3		
60	97	1	0	0		
61	97	2	0	0		
62	99	4	2	8		
63	98.5	4	1.5	6		
64	98	4	1	4		
65	98	4	1	4		
66	98.5	4	1.5	6		
67	98.5	4	1.5	6		
68	99	4	2	8		
69	99	4	2	8		
70	99	4	2	8		
71	99	4	2	8		
72	99	4	2	8		
73	99.5	4	2.5	10		
74	100.5	4	3.5	14		
75	101	3	4	12		
76	100.5	1	3.5	3.5		
77	97	1	0	0		
78	99	2	2	4		
79	99	0	2	0		
80	97.5	2	0.5	1		
81	97	4	0	0		
82	88	4	1	4		
83	98	4	1	4		
84	99	4	2	8		
85	99	4	2	8		
86	99	4	2	8		
87	99	4	2	8		
88	99	4	2	8		
89	100	4	3	12		
90	100	4	3	12		
91	99	4	2	8		
92	99	4	2	8		
93	100	3	3	9		
94	98	3	1	3		
95	98	2	1	2		
96	98	1	1	1		
97	97	1	0	0		
98	--	2	0	0		
99	--	2	0	0		
100	98	2	1	2		
101	97.5	2	1	1		
102	98	2	1	2		
103	97	2	0	0		
104	97	22	0	0		
105	97	2	0	0		
106	97	2	0	0		
107	97	2	0	0		
108	98	0	1	1		
109	98	1	1	1		
110						

Total, 481

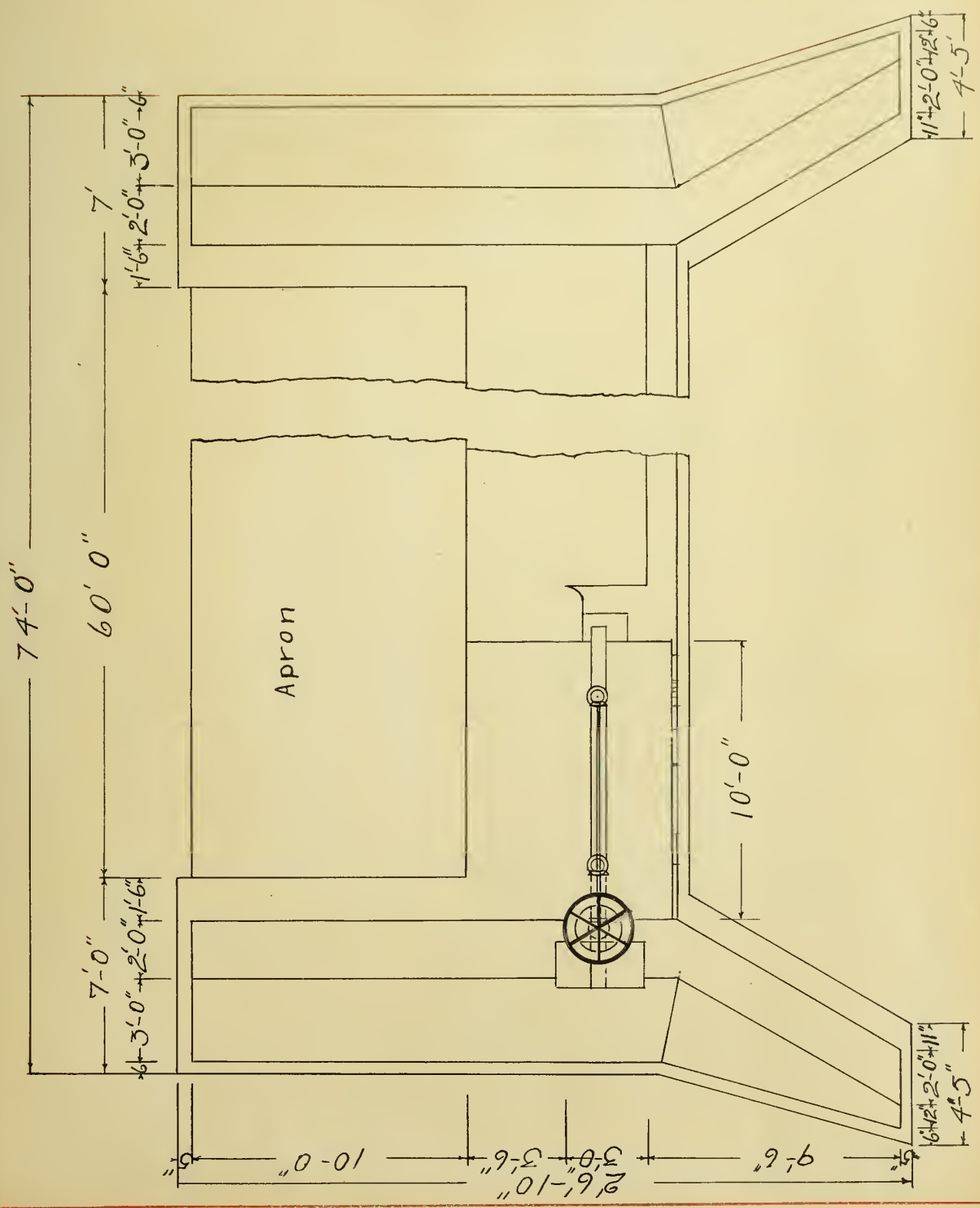
The excavation necessary for the foundation of the dam was calculated by multiplying the section area along the axis of the dam by the width of the excavation.



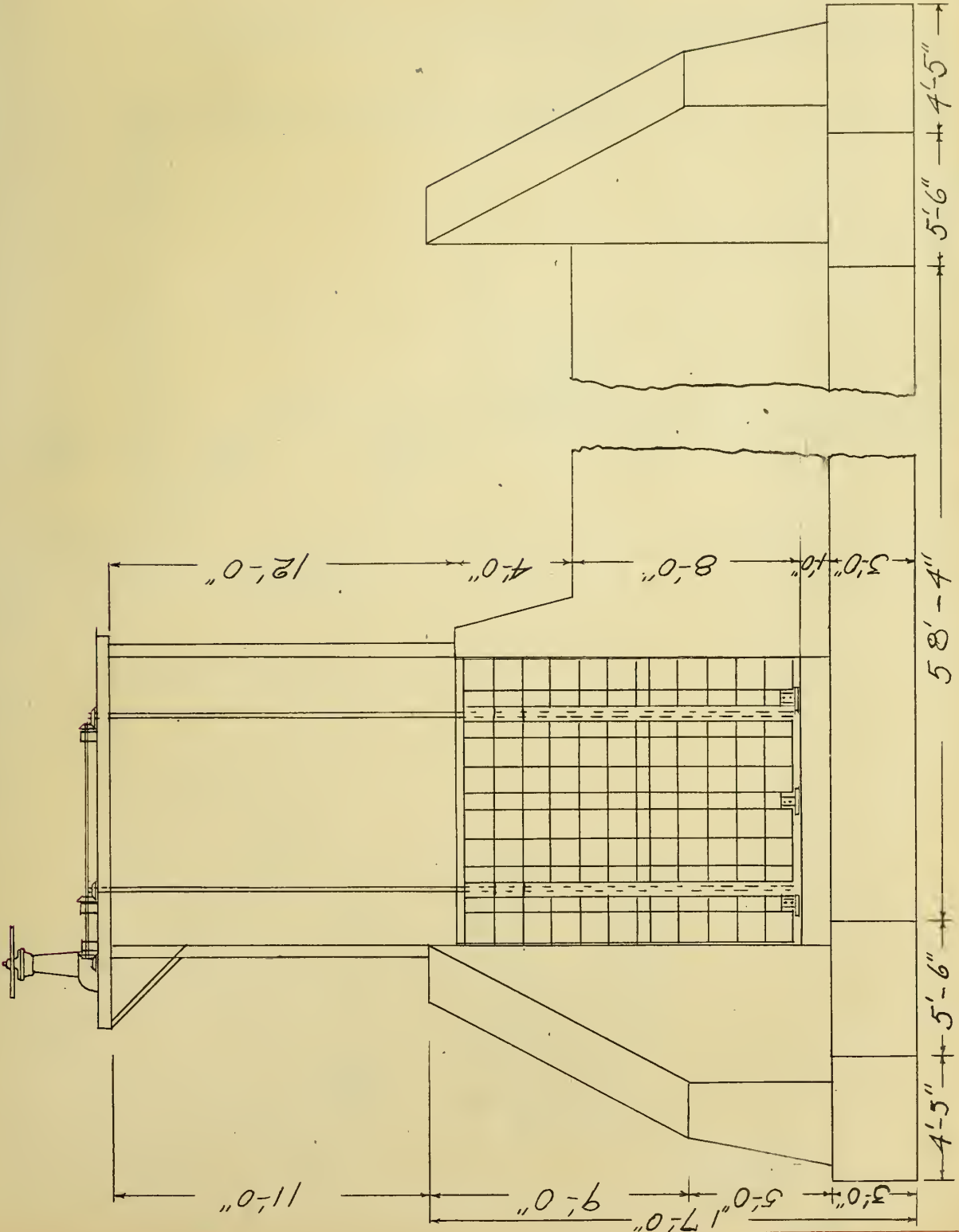
For the main part of the dam, the cross-section is 60 feet in length with varying heights. The area by the offset method is equal to $\frac{d}{2} (a + 2s + b)$ where d = distance between points on the cross section, a and b = the two end depths, and s the summation of the intermediate offsets or depths.

$$\begin{aligned} \text{then area} &= \frac{7.5}{2} (11.5 + 2 \times 49 + 10.4) \\ &= 450 \text{ sq. ft.} \end{aligned}$$

PLAN
FOR
CONCRETE DAM
Scale $\frac{1}{8}" = 1'$ MAY 10, '13
Bullard, E.W.



ELEVATION
OF
CONCRETE DAM
Scale $\frac{3}{16}$ "-1' May 10 '13
Bullard, E.W.



SPECIFICATIONS.

The contractor is to furnish all material and do all work necessary to build an artificial lake on the low grounds of the Central Illinois Chautauqua at Mechanicsburg. The work is to be done in accordance with the specifications and plans.

The work in a general way, consists of clearing the site of the lake, excavating the lake bed and foundation where staked out by the engineer, constructing a masonry dam, wing walls, and apron, and constructing an earth embankment.

(a) Clearing.

The lake is to be cleared of all grass, trees, and shrubbery, and the debris is to be burned.

(b) Excavations.

The excavations shall be made where staked out and the earth deposited as directed by the engineer. The haul is not to exceed 300 ft. Excavations made shall be paid for by the cubic yard measured before excavation.

(c) Dam, Wing Walls, and Apron.

The dam, wing walls, and apron is to be built in accordance with the plans and dimensions furnished by the engineer.

All concrete work shall be paid for by the cubic yard, measured in the finished work and is to consist of $1:2\frac{1}{2}:5$ proportions of cement, sand, and stone or the equivalent in cement and gravel.

The cement is to be of high grade Portland cement and shall comply with the standard specification for cement of the American Society of Civil Engineers.

The sand is to be clear, coarse, and sharp.

Any hard, tough stone free from dust and dirt with a maximum size of 2 inches may be used.

The concrete shall be mixed by a batch mixer or by hand and shall be deposited immediately after mixing.

The forms shall be built true to dimensions and be well braced. Sufficient time shall be allowed for the concrete to set before the forms are removed.

Any cavities which appear after the forms are removed shall be willed with cement and the entire surface of the dam shall be rubbed down smooth.

A gate-way 10' x 8' shall be constructed at the end of the dam as shown on drawings, to be closed by a Caldwell Wilcox Co's standard gate and hand hoist.

Eight-foot piles shall be driven to a depth of 7 feet every 6 foot along the heel and toe of the dam.

(e) Earth Embankment.

The earth embankment for the dam shall start on a well prepared base and shall be built up in 4 inch layers, well rolled. The earth shall be taken from the excavation and shall consist of clay if found. The earth used shall be paid for by the cubic yard and shall be measured before excavated.

If any person appears to the engineer to be incompe-

tent, he shall be discharged on the requisition of the engineer.

Whenever the contractor is not present, orders will be received and obeyed by the foreman in charge of the work.

All changes or extra work desired in the work shall be defined in writing, and the proper addition or deduction made to the contract price, by the engineer.

After the completion of the work, the contractor shall remove all surplus material, the grounds shall be left in neat condition.

The engineer shall at the end of each month make an estimate in writing of the amount of work done and material delivered to be used in the work. The contractor shall be paid 80 per cent of each estimate until 80 per cent of the total contract is paid. The reserve 20 per cent shall be paid upon the satisfactory completion of the work.

ESTIMATE OF COST.

The contractor agrees to receive the following prices, as full compensation for furnishing all materials and for well and faithfully completing the work in the manner and according to the plans and specifications, and the requirements of the engineer, under them.

Clearing site, 8 acres at \$5.00	\$ 40.00
Excavation for lake 7125 cu.yd. at 10 cts.	712.50
Excavation for dam foundation, 456 cu.yd. at 12 cts.,	54.72
Construction of $291\frac{1}{4}$ cu.yds. concrete at \$6.50	1803.12
One Cold Well Wilcox Sluice Gate 10'x12'	<u>420.00</u>
	3030.34

CONCLUSIONS.

It is seen from the design that the construction of an artificial lake on the low lands of the Central Illinois Chautauqua is a possibility. The construction of the Illinois Traction System fill across the valley has made the design an economical and practical one.

The Association has forty acres of valuable land with approximately \$20,000. worth of improvements in buildings, well, etc. The cost, therefore, for construction of the lake is a small item when compared to the capital invested and the benefits to be derived. The attractions offered by a body of water would be a great feature toward increasing the number of patrons of the Chautauqua and would enable the association to again compete with the younger Chautauquas situated on natural bodies or streams of water. The revenue derived from boating and bathing privileges would pay for the maintenance of the lake and possibly return large interest on the money invested.

A rough estimate of the money to be invested, the annual expense and revenue to be derived is given as follows.

10 boats at \$20.00	\$200.00
1 Boat house, at \$200.00	200.00
Cost of construction,	<u>3030.35</u>
	3430.35

Annual expense.

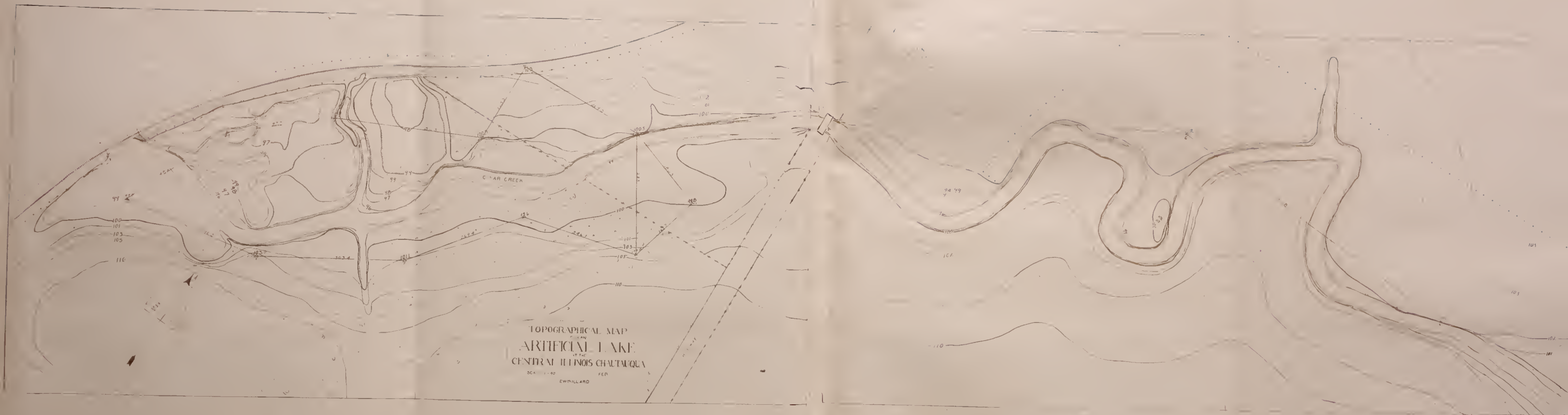
Depreciation on \$400.00 at 8 per cent.	32.00
Interest on \$3430.35 at 6 per cent.	205.82
Labor, 10 days at \$2.00	<u>20.00</u>
	257.82

Annual revenue.

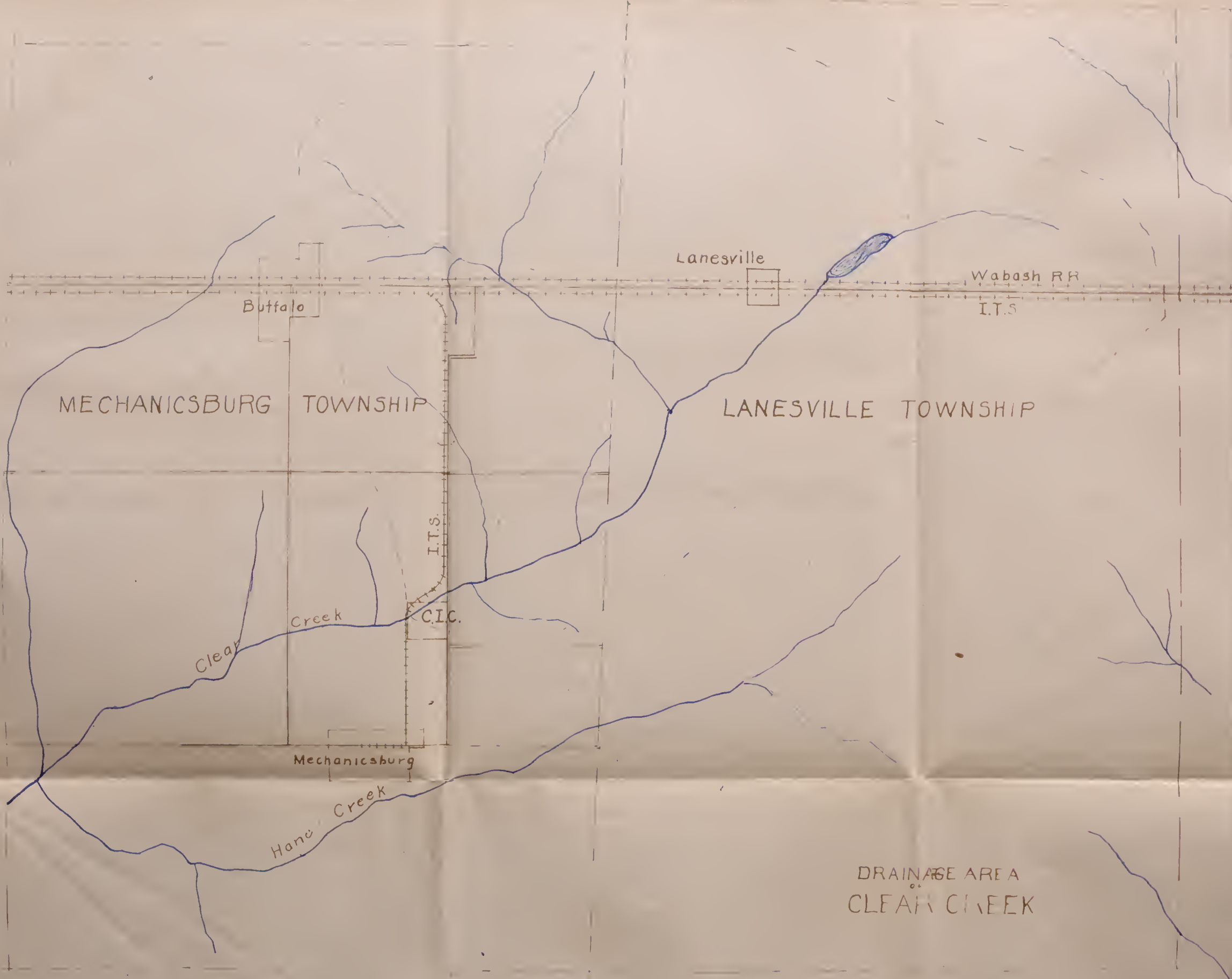
10 boats for 120 hours at 25 cts.,	300.00
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It is also probable that the lake and grounds would be used for picnics, in which case the money taken in will be greatly increased without much extra expense.

The writer wishes to express his appreciation to Mr. R. E. Davis, Instructor in Civil Engineering, for valuable suggestions in connection with this thesis.



TOPOGRAPHICAL MAP
OF AN
ARTIFICIAL LAKE
AT THE
CENTRAL ILLINOIS CHAUTAUQU
DEC 1 - 1907
E. W. HILLARD



Lanesville

Wabash RR

I.T.S.

Buffalo

MECHANICSBURG TOWNSHIP

LANESVILLE TOWNSHIP

I.T.S.

Creek

C.L.C.

Clear

Mechanicsburg

Hane Creek

DRAINAGE AREA
CLEAR CREEK





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